RESEARCH DEPARTMENT

The design of a twin-channel ganged limiter for use with stereophonic programme

TECHNOLOGICAL REPORT No. L – 056

1964/56

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

THE DESIGN OF A TWIN-CHANNEL GANGED LIMITER FOR USE WITH STEREOPHONIC PROGRAMME

Technological Report No. L-056

(1964/56)

T.G. Izatt, M.A.

R.D.A. Maurice

Technological Report No. L-056

THE DESIGN OF A TWIN-CHANNEL GANGED LIMITER FOR USE WITH STEREOPHONIC PROGRAMME

August 1964 Technological Report No. L-056
(1964/56)

THE DESIGN OF A TWIN-CHANNEL GANGED LIMITER FOR USE WITH STEREOPHONIC PROGRAMME

SUMMARY

In order that simultaneous gain reductions of equal magnitude should take place in both channels of a stereophonic system when limiting action occurs in either, it is essential that the pair of limiting amplifiers have accurately matched characteristics, especially in those stages incorporating the variable gain elements. A twin-channel ganged limiter is described, employing the base-emitter junctions of transistors as variable loss elements, having characteristics sufficiently well matched to satisfy this requirement.

1. GENERAL

The purpose of this report is to describe briefly a transistorized twin-channel ganged limiter designed to produce more satisfactory limiting action in a stereophonic programme chain than that which can be obtained with a pair of conventional valve limiters. To avoid unwanted positional displacements of the stereophonic image when the limiter operates, it is essential that the gains of the left- and right-hand channels should remain at all times accurately matched - preferably to within ± 0·25 dB. The control circuits must therefore be cross-connected so that limiting action caused by excessive level in either channel will reduce equally the gain of both channels. Furthermore, not only must each limiter satisfy the usual requirements of noiseless and distortionless operation, but also both must have the same relationship between control bias and gain. This requirement can be fulfilled if the variable gain elements have the same characteristics, or if the circuit in which they are included can be adjusted to remove any differences which may exist between them. In valve limiters provision is made for balancing variable-mu pentodes in the variable gain stages, but this adjustment is applicable to one set of operating conditions only and tends to vary with temperature and time, while the balance requires resetting on changing valves. Thus a pair of valve limiters will not always be sufficiently well matched to permit them to be utilised in a stereophonic programme chain without the need for fairly frequent adjustment.

2. DESIGN DETAILS

The circuit diagram of the left-hand or 'A' channel, consisting of a variable loss stage, a side chain providing the control bias for the variable loss stage, and an

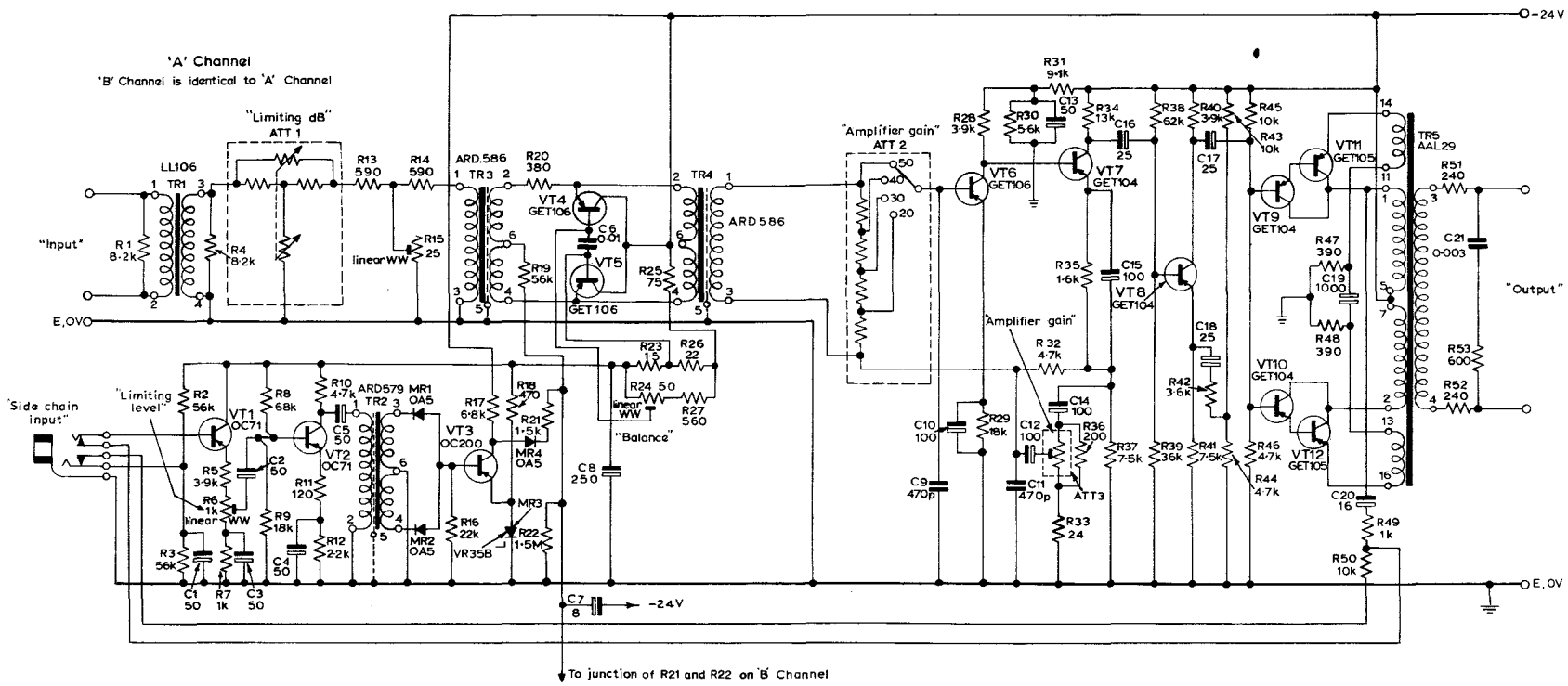

Fig. 1 - Twin-Channel Ganged Limiter - Circuit Diagram

output amplifier, is shown in Fig. 1. The right-hand or 'B' channel is the same, while the capacitor C7 is common to both channels.

2.1. Variable loss stage

Considering a.c. resistances only, the input resistance of the emitter-base junction of a transistor is given by*

$$r_{in} = r_e + r_b(1 - \alpha)$$

where r_e is the equivalent emitter resistance, r_b the equivalent base resistance and α the current amplification factor. For a transistor in common-base connection α is very nearly unity and so the expression for r_{in} reduces to $r_{in} = r_e$. It can be shown* that the value of r_e is given for any transistor by the expression

$$r_e = \frac{kT}{q} \cdot \frac{1}{I_e}$$

where k is Boltzmann's Constant, q is the electron charge, T is the junction temperature measured in °K and I_e is the emitter current. An approximate expression applicable at room temperature is

$$r_e = \frac{26}{I_e} \text{ ohms}$$

where I_e is in milliamps, i.e. the input slope resistance in common-base connection is inversely proportional to the emitter current. Theoretically this characteristic should be exactly the same for all junction transistors, therefore any pair should be matched and also any two pairs should be the same. To discover how far this uniformity exists in practice, junction resistances for four samples each of OC44 s, OC71 s, OC84 s, GET104 s and GET106 s, were measured as a function of emitter current and all the results were found to lie within the limits shown in Fig. 2.

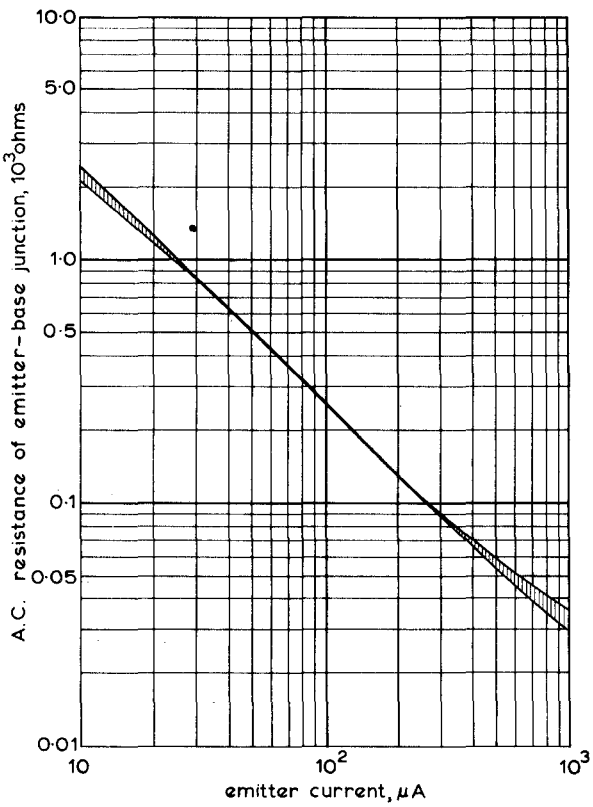

Fig. 2 - A.C. resistance of emitter-base junction as a function of emitter current, measured spread of characteristic for 20 transistors

Referring to Fig. 1, the variable loss stage includes the transformers TR3 and TR4 along with the variable loss elements, transistors VT4 and VT5. The purpose of the resistor R20 is to equalise the d.c. resistances of the two halves of the secondary winding of the transformer TR3 to within 1%, and is necessary to maintain

* For example, Shea, R.F., 'Principles of Transistor Circuits', Chapman & Hall, 1953.

a balanced push-pull circuit. Variable gain is obtained by the emitter-base junctions of transistors VT4 and VT5 acting in series as a variable shunt across the high impedance windings of transformers TR3 and TR4. To reduce distortion of the signal waveform due to the non-linear input characteristics of the transistors and to ensure that the gain of the variable loss circuit is inversely proportional to the control current, it is essential that the transistors VT4 and VT5 be driven from a constant current bias source. This is achieved by feeding the bias to the centre tap of the secondary winding of transformer TR3 through a resistor R19 which is large in comparison with the highest value assumed by the junction resistances within the range of emitter current used.

A push-pull circuit for the variable loss stage has two advantages over a single transistor; the magnitude of even harmonic components of distortion is greatly reduced as is the magnitude of the impulse which occurs in the output when the control bias is suddenly applied. In this respect the design does not differ from that of a conventional valve push-pull circuit as is used, for example, in the limiter type LIM/6A. However, the transistorized variable loss stage has the advantage that the balance, once set, remains fixed. By means of the potentiometer R24, the current flowing through transistor VT4 may be varied relative to that flowing through transistor VT5. Thus the emitter-base junction resistance of transistor VT4 may be altered slightly to remove any residual difference in the total d.c. resistances of the two halves of the push-pull circuit. The circuit is balanced by applying tone to the side chain input by way of the break jack provided, and adjusting potentiometer R24 for minimum amplitude of 'plop' at the output when the tone is switched on.

2.2. Amplifier Stage

Since it is intended that each channel of the limiter should work with zero volume input and deliver zero volume output (i.e. a maximum level of +8 dBm), the variable loss stage, which operates at low level, must be followed by an amplifier of appropriate gain and output impedance. A slightly modified version of the Line Receiving Amplifier AM7/4 is used for this purpose. The input transformer is removed as the necessary balanced input to the first transistor VT6 of the amplifier can be provided by the secondary winding of the variable loss stage output transformer TR4. The output transformer TR5 is changed from one providing a 55 ohm output impedance to one providing a 600 ohm output impedance.

2.3. Side Chain

The input to the first stage of the side chain, with the transistor in emitter-follower connection, is derived from the primary winding of the output transformer TR5. The high input impedance obtained by grounding the collector of the transistor VT1 prevents the input to the side chain from loading the output of the main amplifier.

To provide side chain gain the second stage consists of a transistor VT2 in common-emitter connection, feedback being supplied by an unbypassed emitter resistor R11. The input level to this stage and hence the limiting level is determined by the setting of the potentiometer R6 in the emitter circuit of VT1. From the collector of VT2 the signal is fed to the primary winding of transformer TR2, the secondary winding of which feeds the full wave rectifier comprising MR1, MR2 and

R16. No capacitor is connected across R16 so that the signal applied to the base of transistor VT3, the third stage of the side chain, is a series of negative half waves. The transistor VT3 is maintained in the non-conducting state by the zener diode MR3 in its emitter circuit, and conducts when the zener voltage is exceeded by the peak value of the negative signal at the base. The resultant current flowing through the collector load resistor R17 produces positive pulses which are rectified and smoothed by MR4, R19 and C7 to provide bias for the variable loss stage. Since the capacitor C7 is common to both side chains, any bias produced by either is shared equally between the two variable loss stages. Thus excessive signal level in one or other channel will cause simultaneous and equal gain reductions in both. The capacitor C7 governs the rise and decay time-constants of each channel and is adjusted on test by examination on an oscilloscope of the rise and decay envelopes to obtain time-constants as closely matched as possible to those of a limiter type LIM/6A. The resistor R21 was included to control the rise time-constant, without affecting the decay time-constant.

Leakage current in the collector of transistor VT3 will cause a voltage to appear across C7 and R19 which in turn will have the effect of producing a current flow through the variable loss transistors VT4 and VT5. If leakage current did not vary with temperature, and were the same for all transistors of a given type, the resulting change in the resistance of the variable loss elements VT4 and VT5 would be unimportant. This, however, is not the case. For example, a typical germanium transistor such as the OC71 may have a collector leakage current between 100 and 300 μA. A silicon transistor, such as the OC200, on the other hand, has a low leakage current by comparison, typically 10 nA, and for this reason is chosen for VT3. Any residual leakage current is swamped by a constant bias current flowing in the variable loss stage. This bias, which increases the attenuation of the variable loss stage by only 1·5 dB, is determined in magnitude by R19 and R22 across the stabilised supply voltage, the resistances of the variable loss elements being always small in comparison to R19.

3. PERFORMANCE

The overall gains of the two prototype channels as first constructed were within ½ dB of each other in the non-limiting condition, but were finally equalised by adjusting R15, a pre-set potentiometer included for this purpose. The response-frequency characteristic of each channel, set to accept and deliver zero level tone, is within ± ½ dB from 40 c/s to 15 kc/s. With the limiting level at the output set by means of R6 to be +8 dBm, the input-output characteristic of the A channel is shown in Fig. 3. The gain of the system in the non-limiting condition, normally zero, can be increased in six steps of 1 dB by adjusting a variable attenuator ATT 1 following the input transformer TR1. Over the same limiting range as shown in Fig. 3 the gain of the B channel is within ± 0·1 dB of that of the A channel.

The unweighted noise, measured with an amplifier detector at the output of the prototype, is -60 dBm and the weighted noise* -67 dBm for the A channel, -59 dBm and -67 dBm respectively for the B channel; most of this noise is generated

* Weighted with Aural Sensitivity Network type ASN/3, C.C.I.F. Weighting Characteristics for Noise in Music Circuits, (1949).

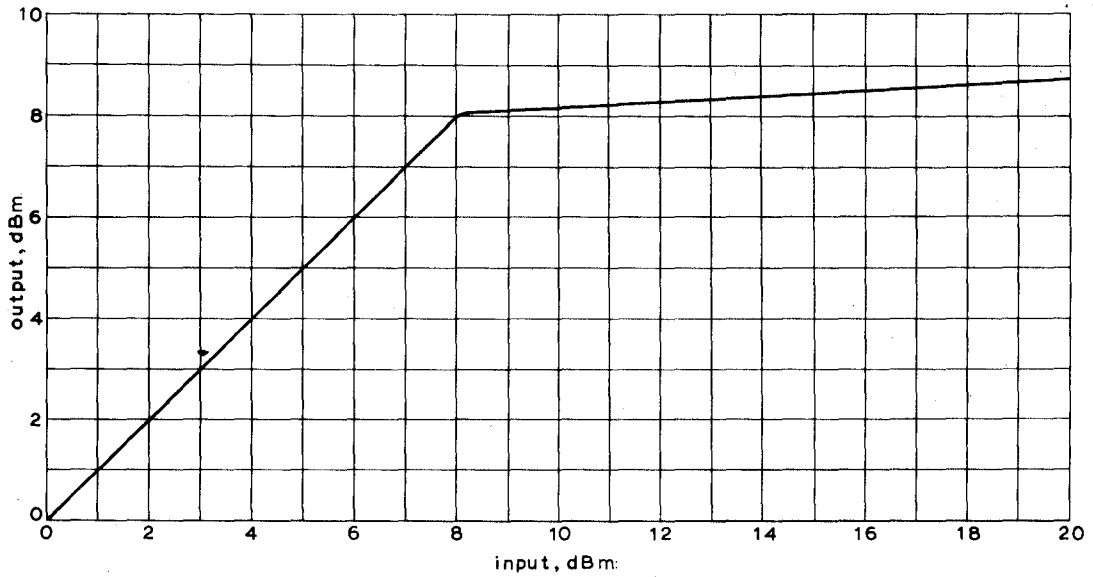

Fig. 3 - Input-output characteristic, A channel. Limiting level at output, +8 dBm

within the output amplifier following the variable loss elements. The harmonic distortion on the output waveforms of both channels is shown in Fig. 4 as a function of the input signal level. The distortion products - mostly third harmonic - amount to 1·1% for 7 dB of limitation; this figure is higher than that obtained with existing equipment employing variable-mu valves, but should be adequate as long as the limiter is not made to act as a compressor. If the signal-to-noise ratio of the output amplifier could be made comparable with that obtained in the corresponding valve amplifier, the variable-gain element could be operated at a lower level, with a consequent reduction in the amount of distortion.

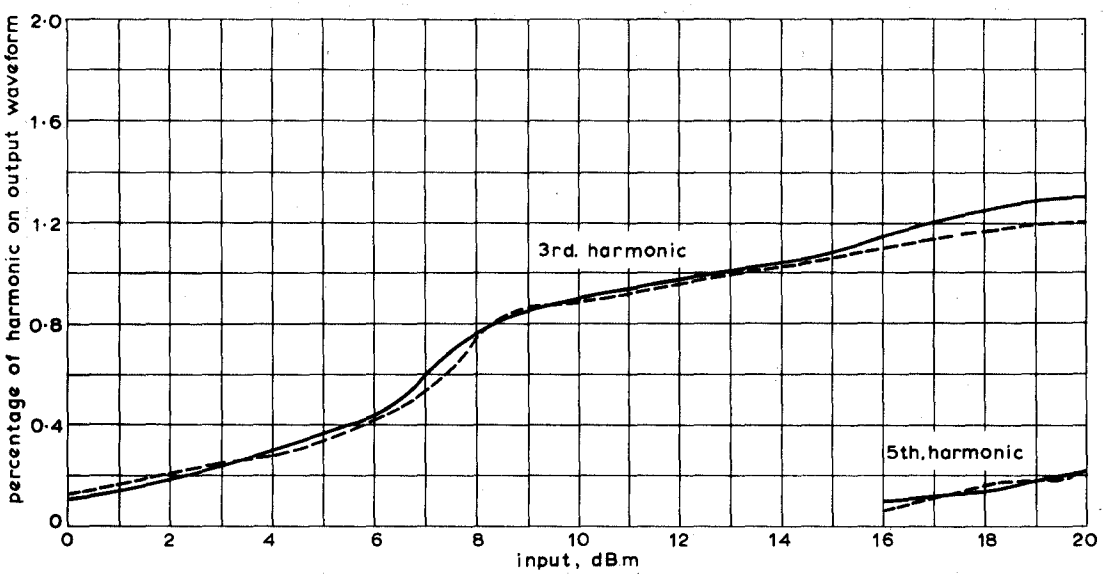

Fig. 4 - Distortion on the output waveform as a function of input signal level

——— A channel — — — B channel

4. CONCLUSION

A transistorized twin-channel ganged limiter has been produced which satisfies the special requirements of stereophony. The characteristics of the variable loss elements are such that accurate matching and stable gain are readily obtained.

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey